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Analysis of Abnormal Wavelength of Diffraction Grating Photometry Wave

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***Abstract*— This paper analyzes the abnormal situation of diffraction grating photometry wavelength, which is an optical experiment in college physics. In the past, only the wavelength of light wave was measured through experiments and the corresponding error analysis was carried out, but there was no special abnormal situation analysis. The main purpose of this paper is to analyze the abnormal situation of grating photometry wave length and make an experiment on the abnormal situation, and then get the influence of the abnormal situation on the experimental result by comparing the theoretical analysis of the abnormal situation with the experimental value.**

Keywords—diffraction grating, abnormal situation, wavelength of light wave

I. Significance of Photometry Wavelength of Diffraction Grating

In the experiment, the diffraction grating was used to measure the wavelength of the light wave, and the method adopted was the vertical incidence method, that is, parallel light was vertically irradiated on the grating. When Formula (1) is met (in which, d is grating constant and φ_k is the diffraction angle of kth order light stripe)[1], the light of the same color will diffract light stripes.

$$d\sin\varphi_k = k\lambda \qquad k = 0,1,2,3,\ldots \tag{1}$$

This method requires parallel light to be vertically incident on the grating, i.e. the incident angle is $\alpha = 0^0$. In the experiment, in order to satisfy the condition of normal incidence of parallel light, plane grating reflection is usually used to adjust. The measured wavelength value is closer to the theoretical value than the double prism interference experiment and the single slit diffraction experiment.

In teaching, because the experiment operation is complicated, the adjustment process is more complicated and requirements are high, an in-depth analysis of the abnormal situation in the experiment is of great significance to both the experimental researchers and the experimental operators, so that they can have a clear idea of the accuracy of the adjustment in the operation process.

II. Analysis of the Abnormal Situation in the Experiment

The diffraction grating photometry wavelength experiment requires the incident light to be vertical to the grating plane and the grating notch to be vertical to the dial. But how high does this vertical degree need to be in order to make the measurement more accurate? When the incident light is not vertical to the grating, there are four types: First, the grating plane is vertical to the incident light, but the notch does not vertical to the dial; Second, the loading plane rotates to left and right, causing the grating to deflect to left and right, and the incident light and grating to be abnormal. Third, the loading plane deflects back and forth, causing the grating plane to deflect back and forth, and the incident light not to be vertical to the grating plane; Fourth, the grating plane and the loading plane rotate clockwise and anticlockwise together, causing the grating not to be vertical to the incident light, but the notch does not be vertical to the dial.

A. Determination of Minimum Deflection Angle in Abnormal Situation

First of all, the left and right deflection of the loading platform causes the grating plane to rotate so that the grating plane is not vertical to the incident light. First adjust the grating plane to be vertical to the incident light, then align the telescope with the light of the measured color light, record the degree of the dial. Then let the inner disc and the loading platform rotate together to see when the observed color light moves obviously, and record the degree of the dial when it just moves. The difference between the measured degree of the dial before and after is the minimum deflection angle $\Delta\theta$ of the grating in abnormal situation.

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When the inner disk is rotated clockwise (i.e. the grating is rotated clockwise), where θ_1 and θ2 are the degrees of the left and right cursors under normal situation and θ_1' and θ_2' are the degree of the left and right cursors in abnormal situation, the experimental data are recorded as shown in Table I and Table II.

TABLE I GREEN LIGHT, THE GRATING CONSTANT IS D=1/N=1/300MM, THE ORDER IS K=-1, $\Delta\theta = [(\theta_1\text{-}\theta_1^{'}) + (\theta_2\text{-}\theta_2^{'})]/2$.

Time	θ_1	θ_2	θ_1'	θ_2'	$\Delta\theta$
1	275.47^0	95.48^0	265.15^0	85.10^0	10.32^0
2	275.25^0	95.23^0	265.15^0	85.15^0	10.10^0
3	275.25^0	95.25^0	265.18^0	85.17^0	10.07^0

TABLE II GREEN LIGHT, THE GRATING CONSTANT IS D=1/N=1/300MM, THE ORDER IS K=+1, $\Delta\theta = [(v_1\text{-}v_1^{'}) + (v_2\text{-}v_2^{'})]/2$.

Time	θ_1	θ_2	θ_1'	θ_2'	$\Delta\theta$
1	248.62^0	68.58^0	246.97^0	66.91^0	1.65^0
2	2489.55^0	68.50^0	247.07^0	67.03^0	1.48^0
3	248.57^0	68.53^0	247.03^0	67.00^0	1.55^0

From the above experimental data, when the loading plane rotates clockwise Δθ=10.140 from green light, i.e. the angle between the grating and incident light is within the range of $79.86^0 \leq \alpha \leq 90^0$, - 1 order diffraction angle changes; When the loading plane rotates clockwise Δθ=1.560, the angle between the grating and incident light is in the range of $88.44^0 \leq \alpha \leq 90^0$, +1 order diffraction angle changes. The experimental results will not be affected by the angle between the green light grating and the incident light with the range of $88.44^0 \leq \alpha \leq 90^0$.

Similarly, the experimental results will not be affected by the angle between the violet light grating and the incident light with the range of $87.64^0 \leq \alpha \leq 90^0$.

B. Record of Experimental Phenomena in Abnormal Situation

TABLE III.GREEN LIGHT, THE GRATING CONSTANT D=1/N=1/300MM, THE ORDER IS $K = \pm 1, \Phi = [(\theta_1 - \theta_1') + (\theta_2 - \theta_2')]/4$

Time	θ_1	θ_2	θ_1'	θ_2'	φ	λ
1	331.67^0	151.67^0	306.67^0	126.67^0	12.50^0	721.47
2	331.68^0	151.68^0	306.67^0	126.67^0	12.51^0	722.03
3	331.65^0	151.67^0	306.68^0	126.67^0	12.49^0	720.90

Green light, the grating constant d=1/N=1/300mm, the order is $k = \pm 1, \varphi = [(\theta_1 - \theta_1') + (\theta_2 - \theta_2')]/4$, the angle corresponding to the central light at the beginning of the inner disc is $\varphi_{左} = 278.00^0, \varphi_{右} = 98.00^0$; After the inner disk is rotated 400 clockwise, the angle of the central light is $\varphi_{左} = 318.00^0, \varphi_{右} = 138.00^0$, as shown in Figure 1. The experimental data are Table III.

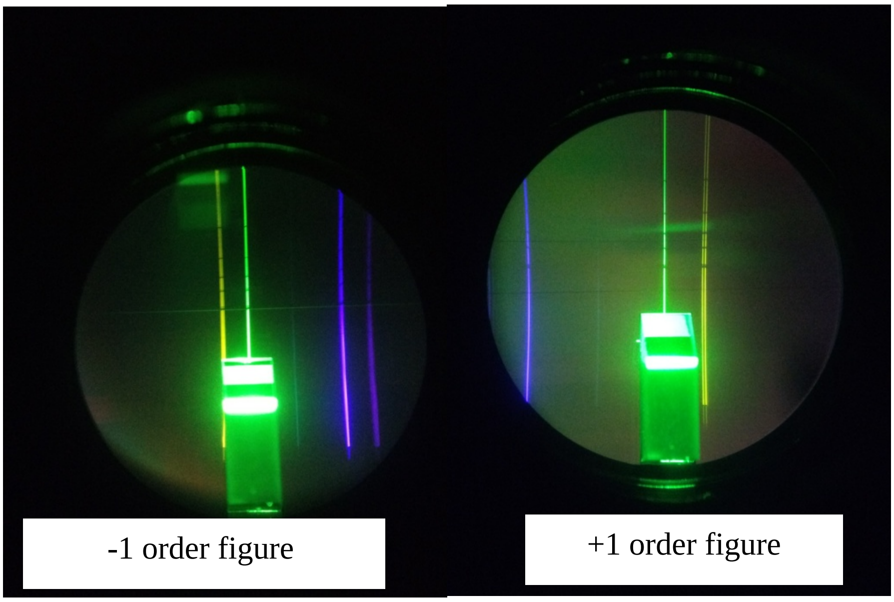

Figure 1.

The abnormal measurement of green light, the wavelength of green light $\bar{\lambda} = \frac{720.90+722.03+721.47}{3}\text{nm} = 721.47\text{nm}$ is obtained by $\lambda = \frac{d \sin \varphi_k}{k}$. $\lambda_{理论} = 546.07\text{nm}$, compare with the experimental values, the theoretical values differ greatly, which means it is not feasible.

TABLE IV VIOLET LIGHT, THE GRATING CONSTANT D=1/N=1/300MM, THE ORDER IS K=±1,$\varphi = [(\theta_1 - \theta_1') + (\theta_2 - \theta_2')]/4$

Time	θ_1	θ_2	θ_1'	θ_2'	φ	λ
1	328.67^0	148.67^0	308.95^0	128.93^0	9.78^0	566.22
2	328.63^0	148.58^0	308.93^0	128.90^0	9.85^0	570.02
3	328.65^0	140.60^0	308.93^0	128.92^0	9.85^0	570.02

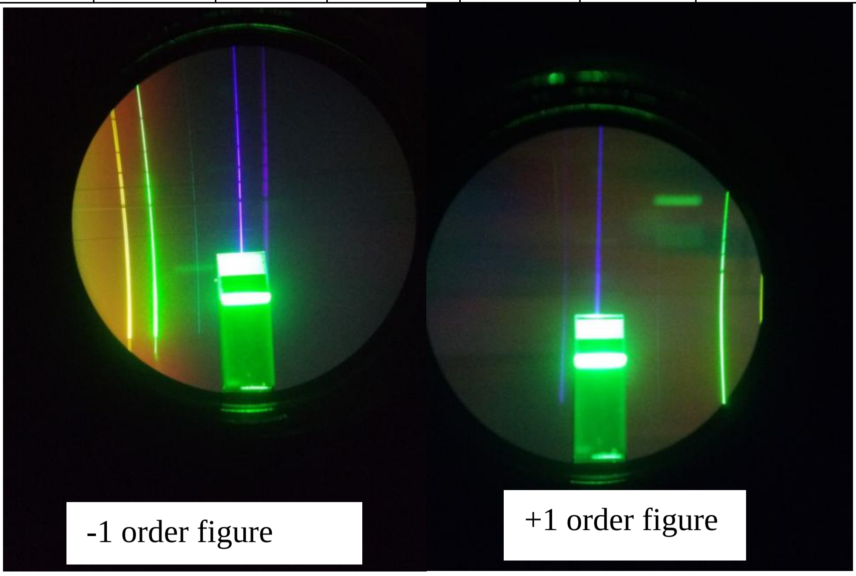

Figure 2.

Violet light, the grating constant d=1/N=1/300mm, the order is k=±1,$\varphi = [(\theta_1 - \theta_1') + (\theta_2 - \theta_2')]/4$, the angle corresponding to the central light at the beginning of the inner disc is $\varphi_{左} = 278.00^0, \varphi_{右} = 98.00^0$; After the inner disk is rotated 400 clockwise, the angle of the central light is $\varphi_{左} = 318.00^0, \varphi_{右} = 138.00^0$, as shown in Figure 2. The experimental data are Table 4.

The abnormal measurement of green light, the wavelength of green light $\bar{\lambda} = \frac{566.22+570.02+570.02}{3}\text{nm} = 568.75\text{nm}$ is obtained by $\lambda = \frac{d\sin\varphi_k}{k}$. $\lambda_{理论} = 435.84\text{nm}$, compare with the experimental values, the theoretical values differ greatly, which means it is not feasible.

III. THEORETICAL ANALYSIS OF ABNORMAL SITUATION

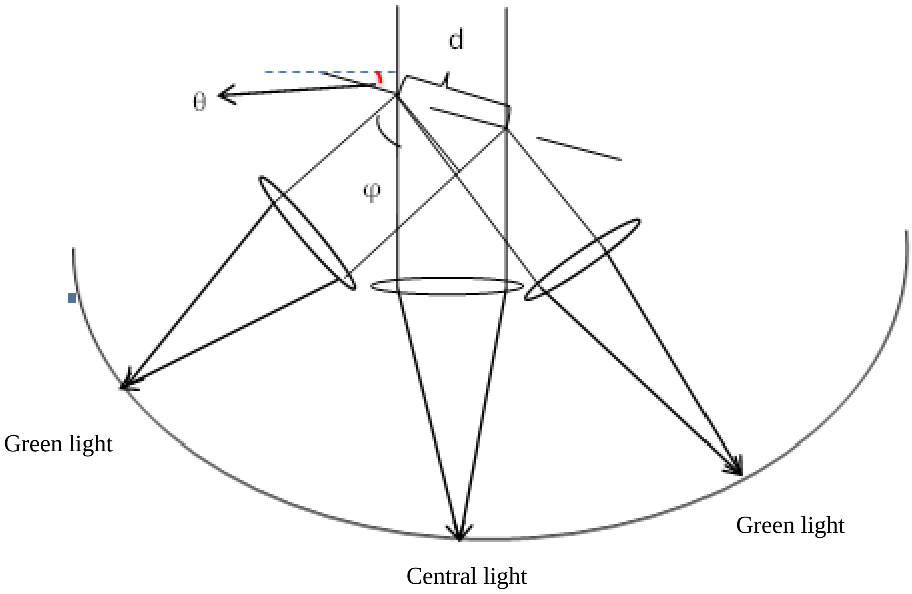

Figure 3.

The optical path difference dsinφ of the light passing through the adjacent slit should be k times the wavelength before light lines appear at the position corresponding to the diffraction angle, thus obtaining the grating equation $d\sin\varphi_k = k\lambda$. As can be seen from Figure3, when the incident light is not vertical to the grating, the grating is deflected clockwise by an angle θ. The angle between the incident light and the outgoing light is taken as the diffraction angle, when the outgoing light is deflected to the left, the optical path difference is dsinθ+dsin(φ-θ). When the outgoing light is deflected to the right, the optical path difference is dsin(φ+θ)-dsinθ . When the light does not deflect, the optical path difference is still zero.

Similarly, when the optical path difference is an integer multiple of the wavelength, light lines will appear at the positions corresponding to the diffraction angles. According to the above analysis, the conditions for the appearance of light lines is (2).

$$d\sin(\varphi+\theta)-d\sin\theta=k\lambda \tag{2}$$

TABLE V.THE GRATING CONSTANT IS D=1/N=1/300MM, GREEN LIGHT.

θ/degree		3	6	10.14	11.4	20	0
φ/degree	*k=+1*	9.48338	9.56604	9.72921	9.79096	10.387	9.4287
	k=-1	-9.4009	-9.3992	-9.4391	-9.461	-9.735	-9.429
Φ average/degree		9.44215	9.48262	9.58415	9.62596	10.061	9.4287
λ/nm		546.84	549.163	554.988	557.386	582.33	546.07
Δφ/min		0.80518	3.23333	9.3252	11.8338	37.945	0
Δλ/nm		0.77017	3.09254	8.9178	11.3162	36.261	0

When the light is deflected to the right, φ is positive and the optical path difference is positive. From this, the diffraction angle equation corresponding to the appearance of light lines is (3).

$$\varphi=\arcsin\left(\frac{k\lambda}{d}+\sin\theta\right)-\theta \tag{3}$$

Table V. is the case of different θ calculated by this equation.

According to the experiment and theory, the following conclusions can be drawn: for the light with larger wavelength, the smaller grating constant is, the higher the measured orders are and the smaller the minimum deflection angles in the abnormal situation are. The minimum deflection angle of the light on the side which is opposite to the deflection direction of the grating is smaller than that on the other side. For abnormal cases, the central relief position remains unchanged. Diffraction angles on both sides are different, and the light on the side which opposite to the grating deflection direction is larger than that on the other side. The distribution of light on the side which is opposite to the deflection direction of the grating is thinner than that on the other side. The intensity of light on the side which is opposite to the deflection direction of the grating is weaker than that on the other side. Before and after the grating deflection, the grating notch has a certain deflection, which has little influence on the measurement.

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